



# Enhanced electrochemical performance of poly(ethylene oxide) based composite polymer electrolyte by incorporation of nano-sized metal-organic framework

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## HIGHLIGHTS

- A solid PEO-LiTFSI/MOF-5 composite polymer electrolyte is prepared.
- Ionic conductivity and electrode interfacial stability are enhanced by MOF-5.
- Decomposition of MOF-5 at 4.57 V decides the steady window at 60 °C.
- Cycling performance of LiFePO<sub>4</sub>/Li cell is improved by MOF-5 filling.

## ARTICLE INFO

### Article history:

Received 11 March 2013

Received in revised form

27 April 2013

Accepted 7 May 2013

Available online 16 May 2013

### Keywords:

Lithium ion battery

Composite polymer electrolyte

Metal-organic framework

Poly(ethylene oxide)

Electrochemical property

## ABSTRACT

In this study, we propose a new filler material (Zn<sub>4</sub>O(1,4-benzenedicarboxylate)<sub>3</sub> metal-organic framework, MOF-5), which is successfully prepared and incorporated in poly(ethylene oxide) (PEO) based composite polymer electrolyte (CPE) by an in-situ method for improving electrochemical properties in lithium ion battery. A highest ionic conductivity of  $3.16 \times 10^{-5} \text{ S cm}^{-1}$  at 25 °C for the composition of PEO-LiN(SO<sub>2</sub>CF<sub>3</sub>)<sub>2</sub> (ethylene oxide (EO):Li = 10:1)/10 wt% MOF-5 is obtained. The anodic steady window of the electrolyte is 4.57 V at 60 °C, which is decided by the decomposition voltage of MOF-5. The interfacial resistances of Li/CPE/Li cells become more stable upon storage compared for that without MOF-5. The reversible capacities of LiFePO<sub>4</sub>/Li solid cells increase at both 60 °C and 80 °C due to the decrease of the cell polarization. In addition, the capacity retention is 45% after 100 cycles at 1 C rate at 80 °C, while there is a sharp decay after 30 cycles in the cells without MOF-5 filling. These results show that MOF-5 is useful to enhance electrochemical properties of composite polymer electrolyte for solid lithium ion battery.

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## 1. Introduction

State-of-the-art technology of lithium ion battery uses corrosive, volatile, and flammable carbonate-based liquid electrolyte which has been considered to be a critical reason for safety risk [1]. The current challenge is to find a safe and efficient electrolyte that would replace liquid organic electrolyte in lithium ion battery. Since Wright firstly reported the observation of ionic conductivity in complexes of alkali metal salts in poly(ethylene oxide) (PEO) [2] and Armand proposed these materials as solid electrolytes in batteries [3], PEO-based solid polymer electrolytes have been widely studied as a safer candidate to replace the

liquid organic electrolyte [4]. However, all-solid-state PEO-lithium salt complexes usually present too low ionic conductivity ( $10^{-6}$ – $10^{-7} \text{ S cm}^{-1}$ ) and poor mechanical properties to be applicable in solid lithium ion battery [5].

It is attractive that the addition of filler, such as alumina [6–8], silica [9–11], SBA-15 [12], and ZSM-5 [13,14], into PEO-based electrolyte can enhance both physical and electrochemical properties. Investigations showed that nano-sized particles with Lewis acidic surface properties are of special interests to increase ionic conductivity [6,15], and those porous fillers with large surface-to-volume are more helpful to stabilize the electrolyte/Li interface [13]. Particularly, ceramic fillers grafted with organic functional groups are endowed with hybrid properties which improve miscibility with PEO, and thus ionic conductivity and stability of the electrolyte are enhanced [16].

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Metal-organic framework (MOF) is one type of materials having inorganic-organic hybrid property, high specific surface area, and ordered micro-porous structure. Due to its unique properties, MOF have been investigated for application in fields such as gas adsorption [17], catalysis [18] and drug delivery [19]. The compound MOF-5 ( $\text{Zn}_4\text{O}(\text{BDC})_3$ , BDC stands for 1,4-benzenedicarboxylate), one of the iconic MOFs, would be an ideal filler for PEO-base electrolyte. Apart from high specific surface area, porosity, and thermal stability, its metal salt can be kept stoichiometric excessive during synthesis [20], thus the excessive  $\text{Zn}_4\text{O}$  clusters form on surfaces of MOF-5 that would enable the sample with Lewis-acidic surface property as-synthesized. However, MOF-5 or any other MOF has never been studied as filler in composite polymer electrolyte (CPE). Therefore, we report herein the facile synthesis of nano-sized MOF-5 and detailed effects on electrochemical performances of the CPE in solid lithium ion battery.

## 2. Experimental

### 2.1. Synthesis of nano-sized MOF-5

Nano-sized MOF-5 was prepared by a solvothermal method.  $\text{Zn}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$  (1.35 g, 99.99%, from Aladdin) and 1,4-benzenedicarboxylate acid ( $\text{H}_2\text{BDC}$ , 0.25 g, 99%, from Aladdin) were consequently dissolved into 150 ml  $\text{N,N}'$ -dimethylformamide (DMF, +99.9%, from Aladdin) in a 250 ml two-neck flask. After supersonic treating, the flask was equipped with a spherical condenser tube and tee coupling. Then the sealed apparatus was degassed by argon, after which 1 ml triethylamine (TEA, HPLC, from Hengxing Reagent) was injected into the reactor under argon protection without stirring. Holding the flask at 25 °C for 7 h resulted in a solution containing white precipitation. The precipitation was soaked in 100 ml DMF for 12 h with 3 cycles to remove the unreacted zinc nitrate and then soaked in 100 ml methylene chloride ( $\text{CH}_2\text{Cl}_2$ , +99.9%, from Aladdin) for 12 h with 3 cycles. The sample was dried in an evacuated oven under 150 °C for 12 h and then characterized.

### 2.2. Preparation of MOF-5/PEO-based CPE

PEO ( $M_w \sim 4,000,000$ , 99.9%, from Aladdin) was dried at 50 °C, and  $\text{LiN}(\text{SO}_2\text{CF}_3)_2$  (LiTFSI, +99.5%, from Shanghai Sinofluoro Scientific Co., Ltd.) was dried at 100 °C for 24 h under vacuum before use. For the in-situ method quantitative PEO and LiTFSI were dissolved by  $\text{CH}_2\text{Cl}_2$ – $\text{CH}_3\text{CN}$  (acetonitrile, AR grade) mixed solution (volume ratio = 9:1, 30 ml  $\text{g}^{-1}$  PEO). Then the PEO–LiTFSI– $\text{CH}_2\text{Cl}_2$ – $\text{CH}_3\text{CN}$  solution was injected to the MOF-5 reactor after the last wash of  $\text{CH}_2\text{Cl}_2$  and magnetically stirred at 800  $\text{r min}^{-1}$  for 12 h under argon protection. Finally, a homogenized colloidal solution was obtained, which was cast and dried into a film at 55 °C for 48 h in an argon-filled glove box. The electrolyte weight does not change upon further heating, indicating a fully dried membrane.

### 2.3. Characterization and instruments

MOF-5: X-ray diffraction (XRD) patterns were collected from a Rigaku/TTR-III powder diffractometer equipped with  $\text{Cu-K}\alpha$  radiation ( $\lambda = 1.5418 \text{ \AA}$ ) at 25 °C. Scanning electron microscope (SEM, JSM-6360LV SEM) and transmission electron microscope (TEM, Tecnai-G<sup>2</sup>20ST TEM) images were obtained. Specific surface area was measured from  $\text{N}_2$  adsorption isotherm at liquid  $\text{N}_2$  temperature of 77 K by a Micromeritics ASAP 2020 system.

CPE: Three types of cells, SS/CPE/SS (SS, stainless steel electrode), Li/CPE/SS and Li/CPE/Li, were assembled to characterize basic electrochemical properties of CPE correlating to lithium ion

battery use.  $\text{LiFePO}_4/\text{CPE}/\text{Li}$  cells were also assembled to evaluate performance of CPE in solid-state lithium ion battery.  $\text{LiFePO}_4$  electrodes were prepared as described in Ref. [21]. All the electrochemical measurements were conducted on a PARSTAT 2273 system (PerkinElmer Instrument, USA). AC impedances of the cells were potentiostatically measured by applying a DC bias with its value equal to open circuit voltage (OCV) of the cell and an AC oscillation of 10 mV. The obtained EISs were resolved by Zview software (Scribner and Associates). The charge–discharge cycles of solid-state  $\text{LiFePO}_4/\text{Li}$  cells were performed on a Land charge/discharge instrument (Wuhan Land Electronic Co., Ltd. China) with cut-off voltages of 2.5–4.2 V. A high-low temperature test-chamber (GDH-2005C) was used to provide a constant temperature environment for test.

## 3. Results and discussion

### 3.1. Characterization of MOF-5 and SEM images of CPE

To identify crystal size and lattice structure of the prepared MOF-5, TEM and XRD were employed. Fig. 1a is the TEM image of MOF-5 where the crystals with 20–30 nm in diameter are observed. Fig. 1b illustrates the XRD pattern of the sample, whose characteristic peaks match well with the theoretical pattern

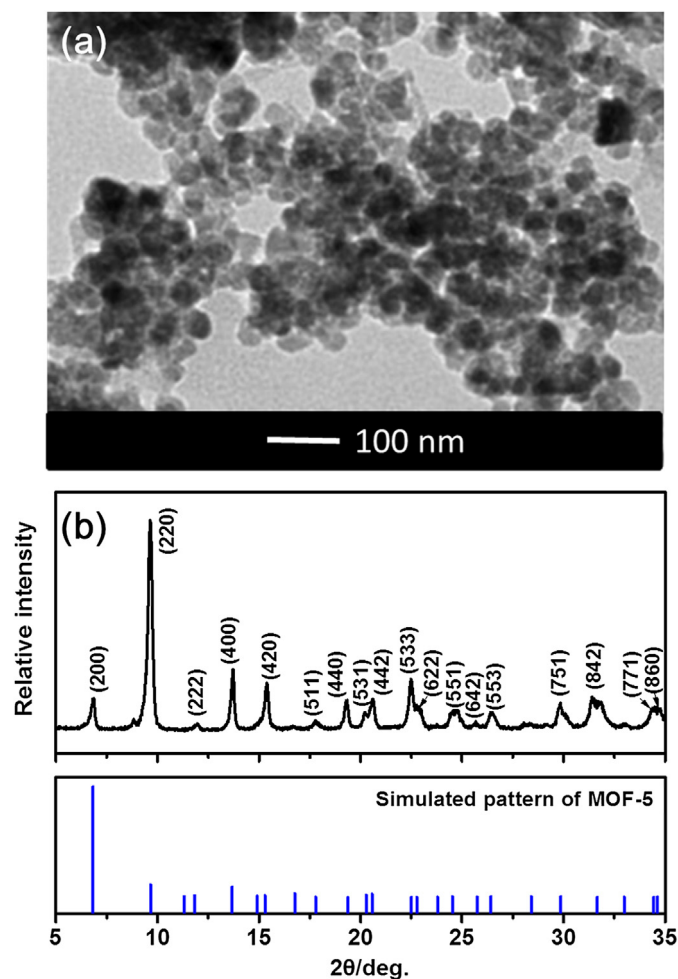


Fig. 1. (a) TEM image of the nano-sized MOF-5 prepared by the solvothermal method using TEA as a deprotonation agent, and (b) XRD pattern of the sample and the simulated pattern based on the crystallographic data of MOF-5 [22].

simulated by the lattice parameters of MOF-5 [22]. Crystal faces for all the peaks are also identified based on the crystallographic data, indicating a successful synthesis of nano-sized MOF-5. But, one can find that the peak intensities at  $6.8^\circ$  and  $9.7^\circ$  are obviously inverted compared with the simulated pattern. Besides, there is a weak split peak at the left of  $9.7^\circ$ . The main reason was previously suggested that solvent residues (DMF, water etc.) in the pores would cause the distortion of crystal symmetry [23]. Although the MOF-5 was dried at  $150^\circ\text{C}$  of the boiling point of DMF for 12 h in this experiment, DMF cannot be completely removed. However, this strong solvent adsorption ability would be an advantage that MOF-5 can effectively prevent the trace solvent from migrating to the electrode interface, which can benefit the interfacial stability of battery.

Generally, PEO/MOF-5 CPE can be prepared either by ex-situ method (blending dry MOF-5 with PEO-LiTFSI- $\text{CH}_3\text{CN}$  solution) or by in-situ method as-described in the Experimental section. Fig. 2 presents the SEM images of the CPE prepared by the two methods mentioned above. By using the in-situ method, more uniform distribution and less agglomeration of the filler material in the CPE are observed. It has been noted that the agglomeration followed by sedimentation can result in less MOF-5 incorporation than the predetermined content that affects ionic conductivity. Therefore, the in-situ method is used to prepare the PEO/MOF-5 CPE in this study.

### 3.2. Ionic conductivity

The impedance spectra of SS/CPE/SS cells are used to obtain ionic conductivity of the electrolyte which is calculated from the real impedance of high-frequency arc intersection with real axis by taking geometry of electrolyte into account.

Fig. 3 shows the effects of ethylene oxide (EO):Li molar ratios of 6:1, 10:1, 16:1, 25:1 and 30:1 on ionic conductivity of PEO-LiTFSI based electrolyte at the same content of MOF-5 (10 wt% of MOF-5 to PEO-LiTFSI) in the temperature range from 25 to  $75^\circ\text{C}$ . Here, the 10 wt% MOF-5 has been experimentally identified as the best loading content. In addition, previous studies found that the heating process of the electrolyte significantly affects ionic conductivity [24,25]. So, the same pretreatments as mentioned in the experimental section were carried out before testing for all the cells. When EO:Li is 10:1 in the CPE, the ionic conductivity is the highest of  $3.16 \times 10^{-5} \text{ S cm}^{-1}$  at  $25^\circ\text{C}$ , and the lowest of  $4.16 \times 10^{-6} \text{ S cm}^{-1}$  as the ratio is 30:1.

Studies reported that the highest ionic conductivity was obtained at EO:Li = 10:1, which is near the eutectic composition of the PEO-LiTFSI system [26]. Since the activation energy used for different phase formation is the same or very close to each other at the eutectic point, the energy barrier of phase transformation in accompany with lithium ion transfer is smaller compared with the

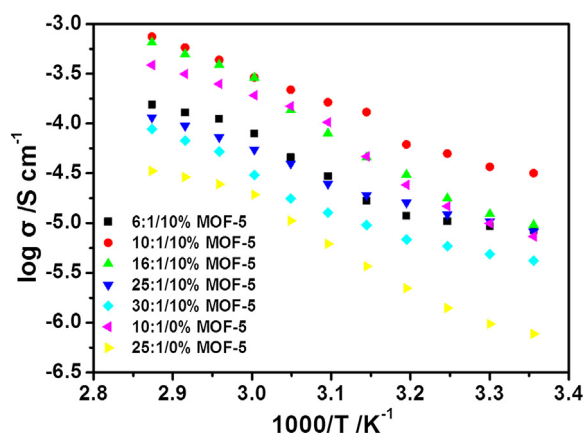


Fig. 3. Effects of EO:Li ratios on temperature dependence of ionic conductivity at the same content of MOF-5 (10 wt%) in the temperature range from 25 to  $75^\circ\text{C}$ , and the comparison of ionic conductivity between electrolyte with 0 wt% and 10 wt% MOF-5 at EO:Li = 10:1 and EO:Li = 25:1 as a function of temperature.

other compositions [27]. Hence, it suggests that there is a similar eutectic effect in the CPE system when EO:Li = 10:1. This is probably the reason for the highest ionic conductivity at EO:Li = 10:1.

Fig. 3 also presents the comparison of ionic conductivity of the electrolyte between 10 wt% and 0 wt% MOF-5 filling at EO:Li ratios both of 10:1 and 25:1. At EO:Li = 25:1, the ionic conductivity is increased by more than one order of magnitude from  $7.70 \times 10^{-7} \text{ S cm}^{-1}$  to  $8.18 \times 10^{-6} \text{ S cm}^{-1}$  in the presence of 10 wt% MOF-5 at  $25^\circ\text{C}$  compared for that without MOF-5, while only four times increased from  $7.36 \times 10^{-6} \text{ S cm}^{-1}$  to  $3.16 \times 10^{-5} \text{ S cm}^{-1}$  at EO:Li = 10:1.

Presumably there are two reasons for the improved ionic conductivity. The major one suggests that Lewis-acidic sites on MOF-5 interact with PEO chains and lithium salt, which will hinder the crystallization of PEO, and benefit to configure  $\text{Li}^+$  conducting passages similar to the structure of  $\text{PEO}_6\text{:Li}^+$  on surfaces of the filler. This interaction also can increase the salt dissolution (see Fig. 4a) [6,14]. When the EO:Li ratio is 10:1, there is a major conductive phase configuration of  $\text{PEO}_6\text{:LiTFSI}$  in the electrolyte [26,28], rather than the phase composition is mainly inactive crystalline PEO at higher EO:Li ratios. Therefore, MOF-5 filler can improve ionic conductivity, especially at lower lithium salt content by influencing the crystalline PEO.

However, there may be another effect that trace solvent absorbed in porous filler will form a facilitated passage for ionic transport in the pore canals of MOF-5 which are isotropic open through three-dimensional direction (see Fig. 4b). But, we think the solvent effect would be mainly confined in the internal cavity of MOF-5

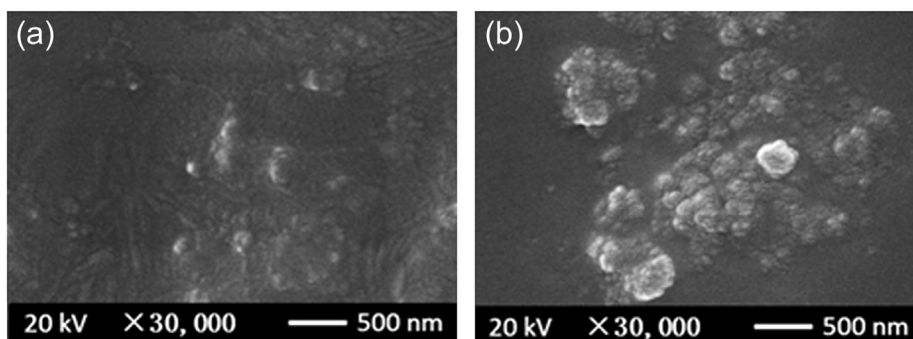
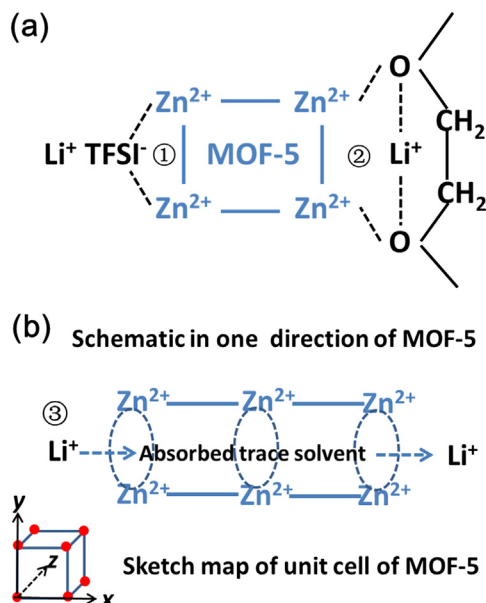


Fig. 2. SEM images of PEO-LiTFSI (10:1)/MOF-5 electrolyte prepared by using the (a) in-situ and (b) ex-situ methods.

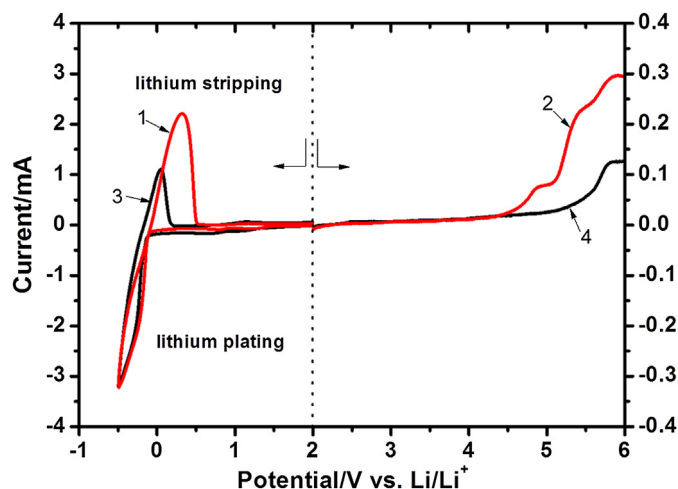


**Fig. 4.** The two schematic diagrams for improved ionic conductivity by MOF-5: (a) Interaction of unsaturated metal sites on the surface of MOF-5 with lithium salt (Li<sup>+</sup> TFSI<sup>-</sup>) and PEO chains (b) ionic transport in the pore canals of MOF-5 which is isotropic open through three-dimensional direction (c).

where the trace solvent is strongly trapped. Otherwise, if the absorbed solvent would transfer to the filler surface and play more important roles, the charge–discharge performance should not have been improved by MOF-5 (the detailed results will be shown in Figs. 8 and 9) when considering the retained solvent (such as DMF, acetonitrile) can react with lithium to form a passivating layer preventing the electrode reaction.

### 3.3. Electrochemical window

Effects of MOF-5 on the electrochemical working window are determined in a Li/CPE/SS cell by the linear sweep voltammetry (LSV) method at a scan rate of 5 mV s<sup>-1</sup>. Since the base line of LSV curves is drifted due to rather low current response at room



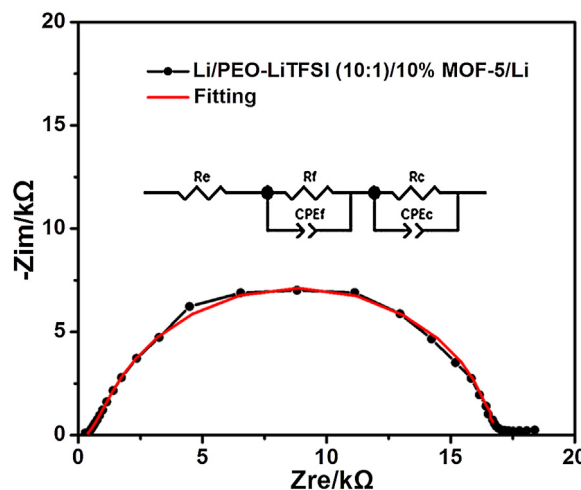
**Fig. 5.** LSV curves of Li/CPE/SS cells with electrolyte compositions of PEO-LiTFSI (10:1)/10 wt% MOF-5 (labeled as 1: 2 V → -0.5 V → 2 V; labeled as 2: 2 V → 6 V, vs. Li/Li<sup>+</sup>) and PEO-LiTFSI (10:1) (labeled as 3: 2 V → -0.5 V → 2 V; and labeled as 4: 2 V → 6 V, vs. Li/Li<sup>+</sup>), obtained at a scan rate of 5 mV s<sup>-1</sup> at 60 °C.

temperature, the LSV was measured at 60 °C. The negative scan (2 V → -0.5 V → 2 V, vs. Li/Li<sup>+</sup>) and the positive scan (2 V → 6 V, vs. Li/Li<sup>+</sup>) are conducted to examine the stability against electrochemical reduction and oxidation respectively. Fig. 5 shows results from two electrolytes with compositions of PEO-LiTFSI (10:1)/10 wt % MOF-5 and PEO-LiTFSI (10:1)/0% wt% MOF-5. As can be seen from the negative scan, both electrolytes have the same reduction potential. But, the lithium stripping peak is more symmetric with the plating peak for the composite electrolyte than the original. The asymmetry for the original electrolyte may be due to the trace solvent irreversibly reduced on the lithium electrode, whereas this reaction is greatly impeded because of solvent-trapping ability of MOF-5 in the composite electrolyte. The high ionic conductivity in the composite system also leads to good reversibility of lithium plating and stripping.

However, the value of the anodic steady window is decreased from 5.19 V to 4.57 V in the presence of 10 wt% MOF-5, responding less electrochemical stable of the CPE than the PEO-LiTFSI electrolyte. The decomposition voltages of the PEO-LiTFSI electrolyte system were previously reported in the range of 4.8 V–5.6 V [29,30], which are comparable with our results. And the anodic current at 4.57 V for the composite system is most likely assigned to the oxidation of MOF-5. The working window of 4.57 V is able to satisfy the requirement of lithium ion battery because it generally operates at lower than 4.20 V.

### 3.4. Interfacial stability against lithium electrode

The high theoretical capacity of lithium (3860 mAh g<sup>-1</sup>) is one of several advantages because lithium is possibly used as an anode material for solid polymer battery [31]. Hence, the interfacial stability at the Li/CPE interface is one of the most crucial factors [32]. In order to investigate such stability, the time dependence of interfacial resistances was monitored by measuring the impedance spectra of Li/CPE/Li cells. The fitting method for the impedance spectra is shown in Fig. 6. A broad and elongated semicircle in the middle-frequency range is apparently composed of two overlapped semicircles. The relaxation time of Warburg diffusion for lithium ion is so long that has made it only demonstrate a depressed response in the low-frequency range. Therefore, the equivalent circuit with the two RC returning circuits is applied to resolve the subtracted skewed semicircle that relates to the passivating layer and charge transfer. The element  $R_e$  denotes the resistance of electrolyte,  $R_f$  and  $CPE_f$ , and



**Fig. 6.** Equivalent circuit adopted to fit the subtracted skewed semicircle in the middle frequency range of the impedance spectra of Li/CPE/Li cells.



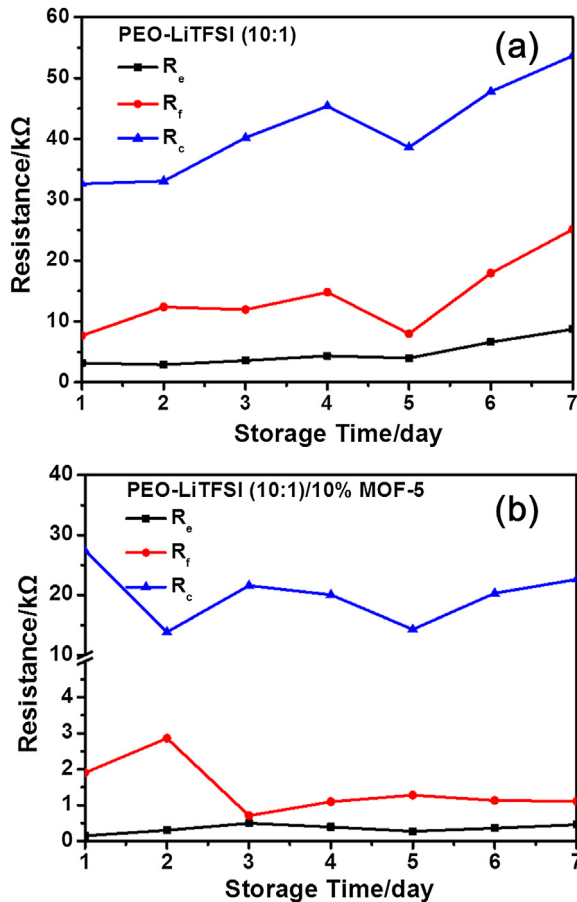


Fig. 7. Storage time dependence of resistances  $R_e$ ,  $R_f$  and  $R_c$  of Li/CPE/Li cells using (a) PEO-LiTFSI (10:1) and (b) PEO-LiTFSI (10:1)/10 wt% MOF-5 as electrolyte.

$R_c$  and  $CPE_c$  (CPE, constant phase element) correspond to the resistance and capacitance of the passivating layer at the electrode/electrolyte interface and charge transfer, respectively [33].

The effect of 10 wt% MOF-5 on the interfacial stability at Li/CPE interface is plotted as the storage time dependence of resistances in Fig. 7. Results exhibit a relatively rapid increase of  $R_e$ ,  $R_f$  and  $R_c$  after 5 days' storage for the electrolyte PEO-LiTFSI (10:1), but more stable and lower values of  $R_e$ ,  $R_f$  and  $R_c$  for the composite electrolyte. Similar increases in stability were observed by other studies with different fillers, such as  $\text{SiO}_2$  [11] and SBA-15 [12], which was generally ascribed to fillers' scavenging capacity of trace solvent impurities [34]. The Langmuir specific surface area of  $784 \text{ m}^2 \text{ g}^{-1}$  for MOF-5 was measured in our laboratory that is higher compared with the fillers mentioned above, which means larger scavenging ability in MOF-5. These results indicate that the ordered nanoporous structure and hybrid properties of MOF-5 not only have strong absorbing ability but also strong trapping ability for trace solvent impurities. Hence, it prevents these impurities from accumulating at the Li/CPE interface to form a passivating layer. This can put in additional advantage of MOF-5 as filler in the CPE.

### 3.5. Cycling of LiFePO<sub>4</sub>/Li solid cells

In order to explore whether the CPE is practically used in a lithium ion battery, its compatibility with LiFePO<sub>4</sub> is preliminarily evaluated. Fig. 8a shows the cycling performance of LiFePO<sub>4</sub>/Li solid cells with electrolyte compositions of PEO-LiTFSI (10:1) and PEO-LiTFSI (10:1)/10 wt% MOF-5 at different rates at 60 °C. When

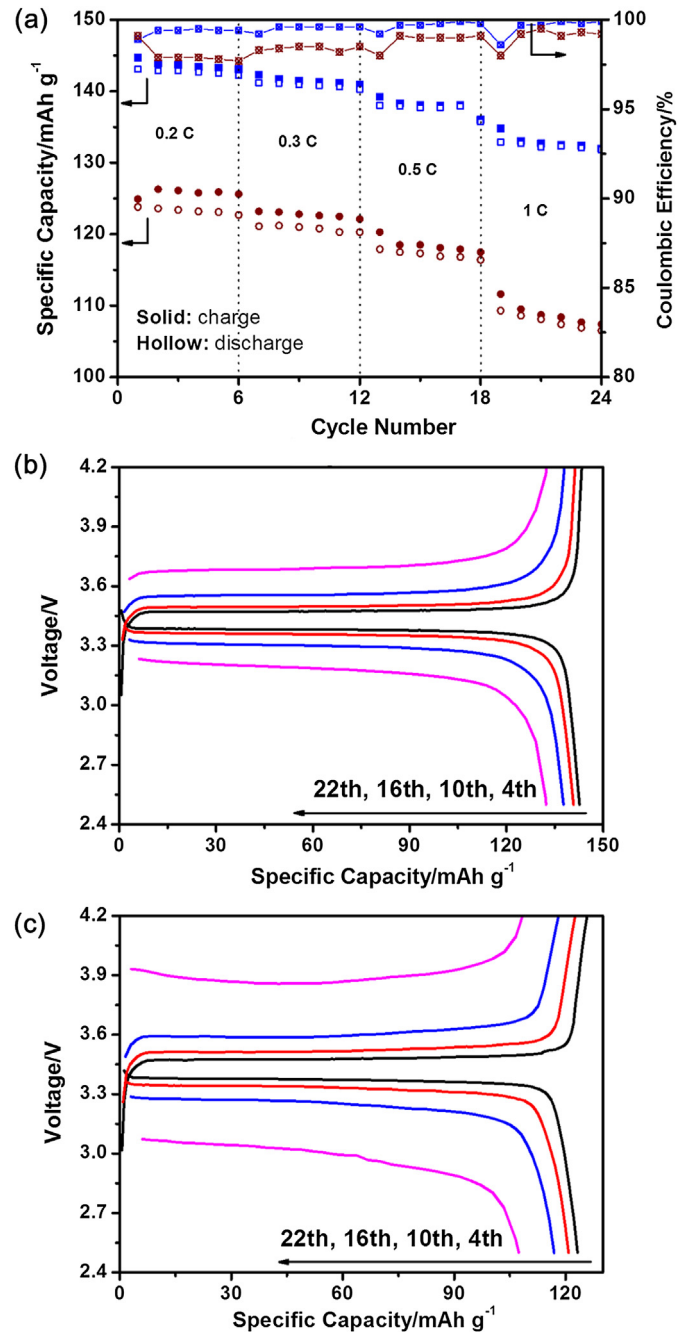


Fig. 8. (a) Rate cycling performance of LiFePO<sub>4</sub>/Li solid cells with electrolyte compositions of PEO-LiTFSI (10:1) (circle) and PEO-LiTFSI (10:1)/10 wt% MOF-5 (square) at 60 °C, and the corresponding rate charge–discharge profiles of that cells (b) with 10 wt % MOF-5 and (c) without MOF-5 at different cycle numbers.

10 wt% MOF-5 was added, increases in reversible charge–discharge capacity from  $126 \text{ mAh g}^{-1}$  to  $143 \text{ mAh g}^{-1}$  at 0.2 C,  $123 \text{ mAh g}^{-1}$  to  $141 \text{ mAh g}^{-1}$  at 0.3 C,  $118 \text{ mAh g}^{-1}$  to  $138 \text{ mAh g}^{-1}$  at 0.5 C, and  $107 \text{ mAh g}^{-1}$  to  $132 \text{ mAh g}^{-1}$  at 1 C are observed. The corresponding rate charge–discharge profiles of the cells with 10 wt% and 0 wt% MOF-5 at different cycle numbers are presented in Fig. 8b and c, respectively. It can be seen that the cell polarization is decreased by MOF-5 filling, especially obvious at higher rates.

Principally, this improvement can be attributed to higher ionic conductivity and lower interfacial resistances after incorporation of MOF-5. The cells using PEO-LiTFSI (10:1) as electrolyte have lower

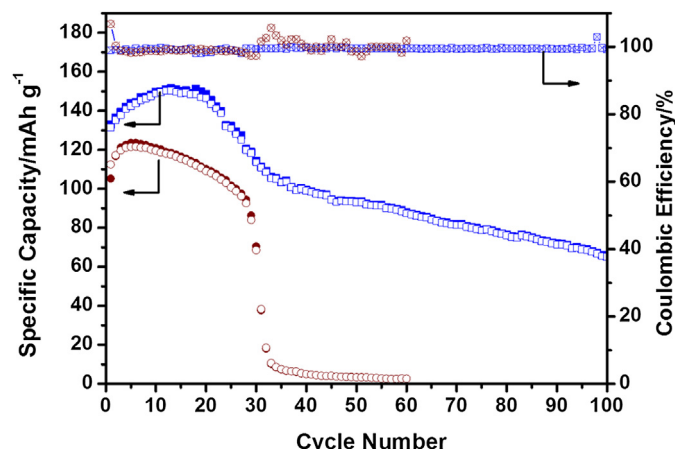


Fig. 9. Cycling performance of LiFePO<sub>4</sub>/Li solid cells with electrolyte compositions of PEO-LiTFSI (10:1) (circle) and PEO-LiTFSI (10:1)/10 wt% MOF-5 (square) at 1 C rate at 80 °C.

Coulombic efficiency than that using PEO-LiTFSI (10:1)/10 wt% MOF-5. This may be due to more side reactions at the electrolyte/electrode interface in the former cells. In addition, the capacity loss becomes more severe at 1 C rate for the original electrolyte than the composite.

The superiority of solid polymer electrolyte over liquid organic electrolyte is that it can work at a much higher temperature range without worrying about safety issues. So we further evaluate the cycling performance of the two kinds of cells at 1 C rate at 80 °C, and the results are shown in Fig. 9. As can be seen, the capacity gradually increases at the initial circles, and then decreases upon cycling for both cells. The first increasing stage may be related to building of Li<sup>+</sup> diffusion paths between electrolyte and LiFePO<sub>4</sub> particles. The capacity can reach to the highest of 121 mAh g<sup>-1</sup> and 151 mAh g<sup>-1</sup> for the original and the composite electrolyte, respectively. However, there is series decay for the two kinds of cells. The cells using the composite electrolyte have 113 mAh g<sup>-1</sup> after 30 cycles, and still retain 45% capacity after 100 cycles. But, the capacity loses completely after 30 cycles in the cells without MOF-5. These results manifest that the internal resistances of cells using composited electrolyte are not significantly changed during cycling. Further intensive investigation is in progress to evaluate the application of the CPE at high temperatures and high rates in large solid cells.

#### 4. Conclusion

The incorporation of filler into PEO-based polymer electrolyte is a low-cost and effective method to improve both mechanical and electrochemical properties of the electrolyte. The effects of nano-sized MOF-5 as filler on electrochemical properties of PEO-LiTFSI based electrolyte are firstly investigated. The highest ionic conductivity of  $3.16 \times 10^{-5}$  S cm<sup>-1</sup> (25 °C) can be presented for the composition of PEO-LiTFSI (EO:Li = 10:1)/10 wt% MOF-5 that is four times higher than the electrolyte without MOF-5. The ionic conductivity increases at EO:Li = 25:1 more than at EO:Li = 10:1 when 10 wt% MOF-5 is added into the PEO-LiTFSI electrolyte. Oxidative decomposition of MOF-5 accounts for response of anodic current at 4.57 V (vs. Li/Li<sup>+</sup>) at 60 °C, which also decides the steady window of this CPE, indicating that is satisfactory for lithium ion battery. Moreover, the resistance stability at the composite electrolyte/lithium electrode interface is greatly enhanced because of the

strong trapping ability of trace solvent provided by ordered nanoporous structure and hybrid property of MOF-5. The reversible capacity of LiFePO<sub>4</sub>/Li cells is increased by MOF-5 filling as a result of reduced cell polarization at different cycling rates at 60 °C. Simultaneously, the capacity retention is rather improved by MOF-5 at 1 C rate at both 60 °C and 80 °C in which the cells can retain 45% capacity after 100 cycles at 1 C rate at 80 °C, while that using the original electrolyte show a quick loss after 30 cycles. These results indicate MOF-5 is proper filler in PEO based solid electrolyte that can be used in solid lithium ion battery.

#### Acknowledgments

This work is financially supported by the National Natural Science Foundation of China (No. 51274239), which is greatly appreciated.

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